

Agro-economic models: a review and directions for research

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ABSTRACT

The article is devoted to reviewing of main 8 models, which are used to analyze the agriculture sector, medium, and long-term forecasts, as well as policy making. The review is based on comparative analysis of models conducted by the authors according to a number of criteria. On its basis, formed the distinctive features of modeling, which are realized in these models. The first distinctive feature is the problem of choosing the level of aggregation in models. This feature generates the direction of research about the effectiveness of the application of one or another aggregation level in modeling. The second distinctive feature of modeling is structurization models into two types: partial equilibrium and computable general equilibrium models. The method of choosing the type of model is one of the actual problems. The third distinctive feature is dominance of deterministic approaches in the construction of models. The use of stochastic analysis in models, in the opinion of the authors, does not yet have a system analysis. Based on the carried out analysis, the authors tried to form directions for the development of the agriculture sector modeling.

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1. Introduction

Modeling of scenarios for global agriculture has become more significant for agricultural policy design. The situation on a world agriculture market such as agricultural and food prices rising and forecasts for real commodity prices cause concerns about the capacity of the agriculture to provide increasing demand. Agro-economic models is the tools, which can help to analyze possible developments in the future and alternative strategies to influence these developments.

Agriculture sector models allow a better understanding of the diversity of interrelations and factors, substantiate causal relationships, study the long-term effects of making decisions, systematically examine trade processes both at the regional and international levels, to conduct scenario calculations and to assess their consequences, etc.

2. Materials and methods

The methodology of analyzing the agriculture sector involves the use of a system of models and their program implementation, which provide multivariate analytical and predictive calculations. There are two types of models for agro-economic system: partial equilibrium and computable general equilibrium models.

Partial equilibrium models (PE) depict the behavioral interactions of the agriculture sector, whilst modeling results in other sectors as exogenous and hence unaffected by development in the sector(s) represented. PE models used to model the impact of development on the agriculture sector most instantly related to a problem (production and use of primary agricultural commodities, including their use as intermediate inputs to agriculture itself).

The feedback of these influences is not modeled in PE models. However, models may include relationships with individual sectors (oil, dairy products, feed concentrate, etc.) with close links to primary agriculture or the economy as a whole (eg land competition based on supply curves). The overall structure of PE models covers technical, accounting and behavioral equations based on statistical data, technical knowledge of the agriculture sector and forecasts of exogenous factors.

PE models are used for a system modeling of interactions in agricultural production of different products with special attention on demand, supply, and prices of different products. PE models consider only the agricultural sector without taking into account the relationships with the rest of the economy.

A computable general equilibrium (CGE) models are used for modeling of the behavior of all participants of the world economy such as producers, consumers, importers, exporters, investors, taxpayers, and government. In CGE models depict the behavioral interactions of the agriculture sector and all economies for one country, a region or even all countries worldwide. CGE models consider inter-industry relations and the influence of international trade on the economy as a whole, as a separate sector. Therefore CGE models are appropriate for modeling of the relationship between agriculture and other sectors in the economy.

In this paper, we compare partial equilibrium models AGLINK-COSIMO, AGMEMOD, CAPRI, ESIM, and FAPRI, and computable general equilibrium models CGERegEU+, GTAP, and MAGNET.

3. Results and discussion

3.1. Overview of the models

AGLINK-COSIMO. It combines two models: AGLINK (OECD) and COSIMO (FAO).The model work for members of both organizations. AGLINK-COSIMO covers 52 countries and regions, and all main areas of agricultural productions.

AGLINK-COSIMO modeling markets factors for the main agricultural products, which are producing, consuming and trading in each of the regions it contains.

The AGLINK country modules are modeling market circumstance and national agriculture policies. The COSIMO modules gives forecasts, which based on an FAO market analysts expertise and model-driven calculations. Therefore modules are integrated to the full AGLINK-COSIMO model.

For each country, an autonomous model is being built, which considers the world market as exogenous variables.

AGLINK-COSIMO has been used in the analysis of the effects of economic growth scenarios on agricultural [1], analysis of commodity balances and trade [2], for agriculture policy modeling [3].

AGMEMOD. AGRicultural MEmber states MODelling used for multimarket modeling with taking to account important factors of the agricultural sector.

The model includes EU-28 members (except Malta) and some nonEU countries. The rest of the world is interpreted as exogenous factors such as world prices, tariffs, and subsidies.

AGMEMOD modeling agriculture of EU as a whole. The model was built at the country level and calibrated for those parameters which could not be estimated. AGMEMOD simulate agriculture sectors feedback to price volatility, government policy, the macroeconomic situation, and other exogenous factors.

The model uses a template for each country. Thus, it allows to provide analytical consistency for all countries and simulate the details. On the countries level, the model reflects agriculture policies which are modeled based on historical time series data.

AGMEMOD has been used in the analysis of agriculture policies [4], impact of some countries on the world market prices [5].

CAPRI. Common Agricultural Policy Regionalised Impact model is modeling the agricultural sector in the EU. The model combines supply and market modules. Supply module includes about 2000 farm regional

models more than 50 crop and animal products for each of the regions and including more than 50 exogenous and endogenous factors. The significance is on crops and livestock.

CAPRI is used by European researches and is often revised. The CAPRI combines a high-level detailing of European agriculture, wide coverage of economic factors, full European and world coverage and the effective network. Therefore CAPRI is used in many different types of research and applications. However, these advantages cause the high price of maintenance costs.

CAPRI has been used in the analysis of free trade agreement [6], land use effects [7], climate change impacts [8], in simulation of reform policies [9].

ESIM. European Simulation Model is modeling supply and demand for the agricultural sector, in particular of cross-commodity linkages. It consists of such policy instruments as quotas, subsidies, intervention and threshold prices, direct payments for keeping land in agricultural use, etc. Policies are modeled only for EU and accession candidates. All behavioral functions in ESIM are isoelastic.

ESIM has two versions: comparative static and recursive dynamic. First version use for medium- and long-term projection of equilibrium states. The second version includes a lagged supply response exists. ESIM takes into account supply and demand shifters. Simulations are typically made for a period of up to 15 years beyond the base period.

ESIM is modeling technological progress in agriculture, agricultural policy and trade EU policy.

ESIM has been used in the analysis of the effects of yield instability on agricultural prices [10], [11], [12], in the analysis of climate change scenarios [13]. Furthermore, ESIM has been used for modeling functioning of factor markets for agriculture [14], [15].

FAPRI. The Food and Agricultural Policy Research Institute model [16] has developed as a system of stochastic modeling with the significance of the agricultural sector in the United States. FAPRI models cover world markets of dairy products, grains, livestock, oilseeds, sugar, and crop insurance. It covers 61 countries. For each of these markets simulated separate models.

FAPRI model combines deterministic and stochastic approaches. The deterministic model analyzes one projection system on 10 years, which based on average conditions of agricultural markets. The stochastic model simulated 500 alternative projections, which based on different conditions of agricultural markets and other exogenous factors. For stochastic modeling, FAPRI uses a Monte Carlo model.

CGERegEU+ model is a system of CGE countries models with emphasis on rural development. It consists of 270 NUTS 2 regions for all EU countries. CGERegEU+ model uses Leontief and Armington assumption. CGE countries models optimize firms profits, consumers utility, the production function, and expenditure.

The model provides modeling of capital, labour, and land. The labour market plays a fundamental role in the CGERegEU+ and allows simulation with fixed wages, the wage curve, or fully free. The rest of the world is modeled as a small open economy model using import supply and export demand functions.

CGERegEU+ can be practiced as a separate model or combined with the CAPRI model. In this case, CAPRI simulates return of capital, labour and land use in agriculture pass to CGERegEU+. CGERegEU+ transfer nonagricultural prices, capital and labour use of agriculture sector to CAPRI.

GTAP. Global Trade Analysis Project model based on perfect competition and use constant returns to scale.

GTAP use multilevel constant elasticity of substitution (CES). It uses for an explanation of factors substitution, in particular, natural resources, capital, labor, and land. Modeling production factors such as energy, animal feed components, also based on this approach. GTAP distinguishes one household for one region. It simulates consumptions incomes, expenditures, savings. The model analyzes government expenditures, regional resources, capital, labor, and land. Thus, for capital and labor markets two possibilities are distinguished. Wage differentials between agriculture and nonagriculture can be sustained in many countries through limited off-farm labor migration.

GTAP has been used in the analysis of the relationship between commodity price volatility and energy prices [17], [18], spillover and welfare effects [19], the impacts of trade policy responses to rising world food prices [20] and graphical exposition of global trade [6].

MAGNET

The Modular Applied General Equilibrium Tool has a modular design that makes adapting the structure of the model to the needs of the researchers. MAGNET allows you to select from a list of non-stand-alone modules that are most likely to be downloaded for research. The original attention is paid to the development of regional agricultural enterprises.

The model shows the importance of the agrarian sector and sales patterns in order to reassure the interests of replacing emissions, changes in the use of land and the relative differentiation of the paid payment between the agricultural and non-agricultural enterprises and the capital stock. At the same time, the template allows for changes in the structure of the elasticity of an inquiry on agricultural trade in goods with a long time due to contingencies of exogenous changes.

MAGNET has been used in the analysis of the economy-wide effects of policy measures [22] [23], climate change impacts [8], and research of functioning of factor markets for agriculture [14].

3.2. Comparison of the models

Once the main model baselines have been described, the main similarities and differences will be shortly discussed. The review will then focus on the main modelling systems used for agriculture policy design. Table 1 provides an analysis of the main properties of models.

Table 1. Comparison of the models

	Model type	Equilibrium type	Baseline definition	Exogenous drivers	World disaggregation
AGLINK-COSIMO	Recursive dynamic	PE	Own baseline projections	Population, macro factors, technical innovation	58 countries regions, including the main trading blocks
AGMEMOD	Recursive dynamic	PE	Own baseline projections	Population, macro factors, technical innovation	EU (except Malta), Croatia, the Former Yugoslav Republic of Macedonia and Turkey
CAPRI	Comparative static	PE	Calibration to DG-AGRI baseline	Population, macro factors, technical innovation	EU28, Norway, Western Balkans and Turkey
ESIM	Comparative static	PE	Calibration to DG-AGRI baseline	Population, macro factors, technical innovation	Only EU, US, Turkey and RoW
FAPRI	Recursive dynamic	PE	Own baseline projections	Population, macro factors, technical innovation	26 countries regions, including the main trading blocks
CGERegEU+	Comparative static	CGE	Calibration to DG-AGRI baseline	Population, macro factors, technical innovation, land, labor, capital	EU
GTAP	Comparative static	CGE	Calibration to DG-AGRI baseline	Population, macro factors, technical innovation, land, labor, capital, natural resources, energy	113 countries and regions
MAGNET	Comparative static	CGE	Own baseline projections	Population, macro factors, technical innovation, land, labor, capital, natural resources, energy	140 countries/regions

In this paper, we investigated different PE and CGE approaches to model agriculture sector. Tables 2 and 3 provides a condensed summary of some of the major studies using PE and CGE models that are reported in this paper.

Table 2. Condensed summary of some key PE analysis

	Study	Area	Contribution
AGLINK-COSIMO	Adenäuer, 2008 [24]	Model comparison	CAPRI versus AGLINK-COSIMO
	Blanco-Fonseca, 2010 [2]	Methodology of the model	Describes and comparison methodology of models
	Kavallari, et al., 2011 [1]	Economics and welfare impacts	Analysis of the effects of economic growth scenarios on agricultural commodity markets
	Himics, et al., 2014 [23]	Model comparison	Comparison AGLINK-COSIMO, CAPRI, and ESIM
	Thompson, et al., 2017 [3]	Methodology of the model	Model developing and scenario analysis
AGMEMOD	van Leeuwen, et al., 2009 [4]	Food-Fuel Tradeoffs	Analysis of the European milk and dairy Market
	Blanco-Fonseca, 2010 [2]	Methodology of the model	Describes and comparison methodology of models
	Fellmann, et al., 2011	Economics and welfare impacts	Analysis of the potential impacts on agricultural markets
	van Leeuwen, et al., 2012 [4]	Economics and welfare impacts	Overview of the Ukrainian agri-food sector
	Bouma, et al., 2012 [5]	Economics and welfare impacts	Impact of Russia and Ukraine on the world market prices for arable crops
CAPRI	Adenäuer, 2008 [24]	Model comparison	CAPRI versus AGLINK-COSIMO
	Blanco-Fonseca, 2010 [2]	Methodology of the model	Describes and comparison methodology of models
	Burrell, et al., 2011 [6]	Food-Fuel Tradeoffs	Analysis of free trade agreement
	Skokai, et al., 2011 [9]	Economics and welfare impacts	Analysis of the European milk and dairy Market
	Himics, et al., 2014 [23]	Model comparison	Comparison AGLINK-COSIMO, CAPRI, and ESIM
	Philippidis, et al., 2017 [25]	Methodology of the model	Model linkage between CAPRI and MAGNET
	Helming, et al., 2018 [7]	Model comparison	The economic, environmental and agricultural land use effects
ESIM	Artavia, et al., 2009 [12]	Economics and welfare impacts	Analysis of the effects of yield instability on agricultural prices
	Blanco-Fonseca, 2010 [2]	Methodology of the model	Describes and comparison methodology of models
	Möller, et al., 2012 [13]	Economics and welfare impacts	Analysis of climate change scenarios
	Shutes, et al., 2012 [14]	Economics and welfare impacts	Functioning of factor markets for agriculture
	M'barek, et al., 2012 [26]	Methodology of the model	Describes the iMAP approach
	Himics, et al., 2014 [23]	Model comparison	Comparison AGLINK-COSIMO, CAPRI, and ESIM
FAPRI	Blanco-Fonseca, 2010 [2]	Methodology of the model	Describes and comparison methodology of models
	Beghin & Xiong, 2016 [21]	Economics and welfare impacts	Economic Effects of Standard-Like Nontariff Measures
	Xiong, et al., 2016 [27]	Economics and welfare impacts	Trans-Atlantic Trade and Investment Partnership and agricultural trade
	Li, et al., 2018 [28]	Economics and welfare impacts	China's Agricultural Import Potential

Table 3. Condensed summary of some key CGE analysis

	Study	Area	Contribution
CGERegEU+	Törmä, 2010 [29] Wania, et al., 2013 [30]	Methodology of the model Economics and welfare impacts	Describes methodology of the model Common Agricultural Policy Regional Impact
GTAP	Britz and Hertel, 2011 [31] Hertel and Beckman, 2011 [17] Satyakti, et al., 2012 [19] Rutten, et al., 2013 [20] Sajedinia, et al., 2014 [32]	Food-Fuel Tradeoffs Food-Fuel Tradeoffs Economics and welfare impacts Food-Fuel Tradeoffs Model comparison	Linking GTAP with CAPRI Relationship between commodity price volatility and energy prices Spillover and welfare effects The impacts of trade policy responses to rising world food prices Comparison of CGE models in case of biofuels policies
MAGNET	Woltjer, et al., 2014 [33] Banse, et al., 2013 [34] Lotze Campen, et al., 2014 [35] Shutes, et al., 2012 [14] Philippidis, et al., 2017 [25] van Meijl, et al., 2018 [8] Helming, et al., 2018 [7]	Methodology of the model Economics and welfare impacts Economics and welfare impacts Economics and welfare impacts Methodology of the model Model comparison Model comparison	Describes methodology of the model Analysis of the economy-wide effects of policy measures Comparing results from AIM, MAGNET and PE Models Functioning of factor markets for agriculture Model linkage between CAPRI and MAGNET Comparison of climate change impacts Model linkage between CAPRI and MAGNET

3.3. Implication of the stochastic component into agro-economic modeling

The considered in our review models include quite a lot of parameters that have stochastic nature. These include, in particular, crop capacity and product prices. The stochastic nature of crop capacity is well illustrated by the example of wheat production in the two largest EU countries – Germany and France. Data analysis (by using www.factfish.com/statistic-country) over a period of 20 years (from 1998 to 2017) indicates range 8,5 bln.tons for Germany and 13,2 bln.tons for France (standard deviations are 2,39 bln and 3,31 bln correspondingly). Graphs are presented at Fig.1. Illustration of wheat price stochasticity is done at Fig.2. It is possible to observe analogous stochastic properties in most prices of agricultural products if not all (rice, sugar, coffee, soybean and so on) (as ex. [36], [37],[38]).

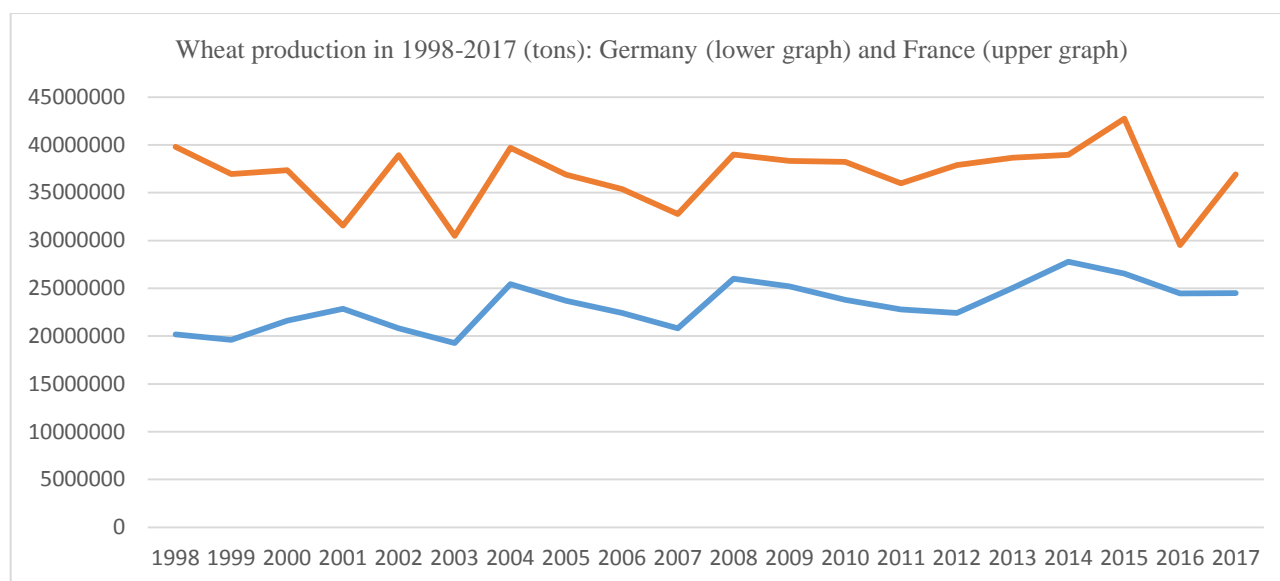


Figure 1. Volatile of wheat crop capacity in Germany and France



Figure 2. Volatile of wheat price

The stochastic component also presents in the institutional context. Export and import values of agricultural products may essentially vary as a consequence of policy changes, tariffs changes etc. Ukrainian example can be used for illustration. After the revolutionary events in 2014, a declaration of association with the European Union was signed. Export of cereals from Ukraine to EU have increased since 2014: it is 58,12 bln.tons in 2017/2018 in comparison 29,30 bln.tons in 2013/2014 (increasing two times).

The stochastic nature of the model's constituent elements generates risks associated with the adequacy of the modeling results and forecasting. Therefore, in our opinion, the implementation of stochastic analysis can be one of the important directions in the further development of this modeling and its application. Based on such analysis risk of deviations from baseline results can be carried out.

It should be noted that stochasticity is considered in most of the models which we examined in this review. Our review can identify three approaches for analyzing the stochastic component. First approach is a scenario approach (example, AGLINK-COSIMO, FAPRI and other). Such approach is useful for elaboration design of decision making in different scenarios. The second approach consists in applying Monte Carlo simulation. This method is applied in models FAPRI, ESIM and some others. It is interesting that application ESIM supposes to estimate the variance of results which modeled by Monte Carlo simulations. This is one of a

number of approaches for the estimation validity of modeling. The third approach is based on sensitivity analysis which can be applied on the post-modeled stage (example CAPRI).

Based on our review and analysis we think, that the extension of the systematic application of risk assessment is the potential effective direction. Now models involve only a couple of approaches from their wide spectrum. We think that it will be fruitful to consider the application of the ISO 31000 “Risk management – Principles and guidelines” (ISO 31000) for constructing methodology of the stochastic component into the agro-economics models. In such a way possible to apply first of all risk assessment activity: risk identification, risk analysis, and risk evaluation. Risk identification should define main risks involving into the model considering (volatility of crop capacity, price changing etc.). Risk analysis includes a number of methods which supplement above mentioned. Especially, statistical, analogical and expert methods of risk analysis may be applied before “model launching”. Also, it is important to construct some risk measures which assess possible deviations from the results of modeling.

4. Conclusion

Modeling of agro-economics is the dynamically developing sphere, which has a lot of facets. In our review, we presented a comparative analysis of 8 models and tried to identify possible directions of conceptual development on its basis.

The first distinctive feature of this modeling is the problem of choosing the level of aggregation. Aggregation can include both the world level (for example, models MAGNET or GTAP), and regional (many models are focused, in particular, on the EU agricultural sector). At the same time, we see the openness of the question about the effectiveness of choosing/applying models of various levels. It is especially interesting how effective the application of the «ROW» approach in regional models.

The second distinctive feature of modeling is structurization models into 2 types - partial equilibrium and computable general equilibrium models. Each type of model has certain strengths and weaknesses. Typically, PE models measure outputs and inputs in physical units (metric tons, hectares, heads etc.), and not, as in CGEs, as dimensionless quantity indices. This not only allows for the inclusion of technical links, but also policy tools such as quotas, tariffs can be modeled so that they are in line with legal and regulatory constraints. This facilitates both the connection with market experts and linkages to biophysical tools, as well as the calculation of environmental indicators. Although the share of agriculture in the economy is shrinking, there is a growing need for modeling tools that can analyze trends in the world market, take into account recent political developments and EU enlargements, and provide a sound basis for policy design. The PE models detail the product characteristics and relationship between them. Their feature is the flexibility in modeling agrarian policy and its tools. CGE models are often modeled in a less aggregate manner, mainly due to the high aggregation of products and less flexibility in the description of agricultural policies. But CGE models are well suited for representing a variety of relationship between agriculture and other sectors of the economy. To combine the advantages of both model types, the PE model and the CGE model, it is a promising analytical approach to integrate CGE and PE models to analyze agricultural policy scenarios. In case of using a subset of all variables being endogenous in both of the models, the integration of simulation models should be an iterative process which uses two models at different aggregation stages.

The third distinctive feature of modeling is a certain dominance of deterministic approaches in the construction of models. The certain baseline is typical results of such approach. At the same time, some methods are used to display the stochastic nature of the constituent elements of models. There are scenario method, Monte Carlo method and the sensitivity method most often used. In our opinion, the systematic application of the approaches of stochastic analysis and risk management is one of the promising areas of modeling agro-economics.

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